ANALYSIS OF FLORIDA TRANSIT BUS CRASHES

BUS CRASHES

Final Report

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16. Abstract

Through its National Center for Transit Research, and under contract with the Florida Department of Transportation, the Center for Urban Transportation Research was tasked with reviewing a sample of transit bus crash occurrence data from selected Florida transit systems. The purpose of this review is to analyze changes in crash occurrence over time in relation to the effectiveness of training programs and capital safety improvements in reducing bus crashes. In addition to promoting safety, it is believed that this effort can serve as the first step in establishing a general list of safety campaigns, along with related costs and "rule of thumb" occurrence prevention effectiveness levels for each. A list of this nature will aid transit systems in Florida, the U.S., and elsewhere in the selection of safety campaign(s) that will meet their financial and safety goals.

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INTRODUCTION

Through its National Center for Transit Research (NCTR), and under contract with the Florida Department of Transportation (FDOT), the Center for Urban Transportation Research (CUTR) was tasked with reviewing a sample of transit bus crash occurrence data from selected Florida transit systems. The purpose of this review is to analyze changes in crash occurrence over time in relation to the effectiveness of training programs and capital safety improvements in reducing bus crashes. In addition to promoting safety, it is believed that this effort can serve as the first step in establishing a general list of safety campaigns, along with related costs and "rule of thumb" occurrence prevention effectiveness levels for each. A list of this nature will aid transit systems in Florida, the U.S., and elsewhere in the selection of safety campaign(s) that will meet their financial and safety goals.

It is important to note that this evaluation is a follow-up study to CUTR's project on "Enhancing Safety In Florida Transit Systems," which was completed in June 1998. This previous project evaluated and documented State and Federal regulations in place at that time regarding safety in the public transit industry. Further, it developed a process to help Florida transit agencies track and analyze their bus crashes in order to help them determine common causal factors and/or measure the success of their crash prevention efforts. The expectation of this particular project was that increased capabilities in tracking, analyzing, and preventing crashes could help systems reduce their costs, while also making transit a safer and more attractive transportation alternative.

CASE STUDY SELECTION PROCESS

CUTR commenced its investigation by researching large Florida transit systems that had undertaken safety campaigns in the last few years. For this project, a safety campaign will be defined as a system-wide change in operator training or vehicle function that has been implemented to promote safety and reduce the number of occurrences within a system. A larger transit system is necessary for this analysis in order to collect enough occurrence data points to receive statistically significant results. Ideally, a selected system would be able to supply occurrence data ranging from one year prior to the start of the safety campaign to one year after the safety campaign has been fully implemented.

After an initial evaluation of Florida's larger transit systems, and with guidance from FDOT, two systems were ultimately selected for this investigation: Hillsborough Area Regional Transit Authority (HART) in Tampa and LYNX Transit in Orlando. One system, HART, represents a safety campaign that demonstrated a change in operator training. The second system, LYNX, represents a safety campaign that demonstrated a capital improvement to the vehicle (i.e., rear-end high density lights). This report documents the case study analyses of these safety campaigns and their effectiveness in positively impacting crash occurrence at HART and LYNX.

ANALYSIS METHODOLOGY

To begin the analysis of the safety campaigns implemented at each of the case study transit systems, the systems first were contacted to discuss the project scope and goals, encourage participation, and identify a primary contact person for subsequent communication, information requests, and questions. Meetings were held with agency representatives at the outset of the effort to help establish data requirements for the evaluation. In the case of HART, this meeting was held with system safety personnel (in addition, at a separate meeting, a presentation was made to senior staff to help them understand the purpose of the project and how it would benefit the system). A similar meeting was held at LYNX with the Director of Planning and Development.

After the successful recruitment process, CUTR staff worked with system contacts to collect information regarding their respective safety campaigns, as well as pre- and post-implementation occurrence data. This process turned out to be considerably more arduous than originally anticipated due to the involvement of multiple departments at the systems, risk management concerns, and data compilation issues at the systems. One major problem involved concerns for maintaining driver anonymity. This particular concern necessitated CUTR having to rely on system personnel to provide the necessary occurrence data, rather than pulling the information directly from accident reports, as was originally planned. This concession resulted in a significantly longer data collection process. Ultimately, however, both HART and LYNX were able to provide enough occurrence information with which to conduct a statistically-valid assessment of the effectiveness of their safety campaigns.

After retrieval of the appropriate occurrence information, Microsoft Excel was utilized to sort the data and arrange it into a format suitable for statistical analysis. The data collection effort was geared to ensure that each occurrence data record included the following descriptive variables: type of involvement; date, time of day, and day of the week of the occurrence; preventability status; location; vehicle number; route number; general direction; operator tenure (i.e., years of

experience); weather conditions; and type of occurrence impact dynamics. Statistical analysis of the data was then completed using the Statistical Package for Social Sciences (SPSS). SPSS is a powerful PC-based program that allows one to manipulate data to generate descriptive statistics, as well as time series regression analyses. Frequencies and cross tabulations were completed for selected data points. The results of these analyses for each of the case study transit systems are described in the following sections.

It should be noted that the following definitions apply for this project and its documentation. A **crash** is defined as a collision between a transit vehicle and another motor vehicle or person/ thing. An **incident** is defined as an altercation or slip-and-fall that occurs on the transit vehicle or while boarding/exiting the transit vehicle. An **occurrence** will be defined as either a crash or an incident involving a transit vehicle.

HART CASE STUDY: BUS OPERATOR REFRESHER TRAINING COURSE

The Hillsborough Area Regional Transit Authority is an independent authority that provides fixed-route motorbus and demand response services to all of Hillsborough County (excluding Plant City). According to FY 1999 National Transit Database information (the most recent year for which validated NTD data are available), HART's service area encompasses approximately 273 square miles, with a service area population totaling over 922,000 persons. Fixed-route motorbus service is provided seven days per week using a peak fleet of 158 vehicles. HART provided more than 5.4 million revenue miles of service in FY 1999, generating a total of 9.3 million passenger trips. Due to the number of vehicles in operation and the amount of service miles operated, it was determined that HART was suitably sized to conduct a statistically valid occurrence analysis.

HART performed a systemwide operator refresher training course during a three-month period in 1998. Therefore, the objective of this first case study is to examine both the systemwide and seniority-level effects that such refresher driver training has on crash occurrence. In particular, CUTR is interested in the effect that the training had on HART's skilled/veteran operators who had not taken a refresher course since the initial new operator training course they completed when they first began driving for the system. In the "Enhancing Safety In Florida Transit Systems" project, it was surmised that a refresher training course would most benefit experienced operators who have become complaisant in their safety knowledge and/or driving skills. This particular case study will test this premise. It is anticipated that the results of this case study will help systems better understand the beneficial effects of refresher training and will help establish an optimal time cycle for scheduling such training.

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As mentioned previously, between May and July 1998, HART performed a system wide operator refresher training course. Regardless of prior driving record or level of seniority (i.e., experience), all HART operators were required to participate in the course. The course was designed to be completed in a single day (approximately eight hours in length), with time allocated for discussion in each of the study modules. The itinerary for this course, as provided by HART, is provided below.

HART Refresher Training Course Itinerary

7:00 a.m.	❖ Customer Service – 2 hrs. ▪ Show Video ▪ Review Handout – "Dealing with Difficult People"
9:00 a.m.	❖ Defensive Driving – 2 hrs. ▪ Show Videos ▪ Overhead Transparency Presentation – National Safety Council ▪ "Guide to Determine Motor Vehicle Accident Preventability"
11:00 a.m.	Lunch
12:00 p.m.	❖ ADA Sensitivity – 45 min. ▪ Review Handout
1:30 p.m.	❖ Drug Free Workplace – 45 min. ▪ Review Policy
2:15 p.m.	❖ Policies and Procedures – 45 min. ▪ Review Swipe/Flash/Punch Pass Handout ▪ Review any other specific policy/procedural questions on topics such as Baby Strollers, Transfer Policy, etc. Use Master Memo Books.
3:00 p.m.	❖ Bus Component Review and Wheelchair Securement – 1 hr. ▪ Review all control and emergency switches and securement systems.

Special Notes: Depending on time frames, try to allow for some discussion in each segment. If necessary, class can run longer than eight hours in order to complete entire training module.

In order to evaluate the effectiveness of this safety campaign, occurrence information was requested from HART for the time period from October 1996 to November 1999 (this span of time will henceforth be referred to as the "study period").[1] This range of data would allow for the analysis of at least one year's worth of occurrence data both prior to and after completion of the refresher training course. Along with the requested occurrence information, blank hard copies of HART's supervisor, operator, and witness reports also were collected. HART utilized its FleetNet software and an electronic occurrence database that staff generated from information included in the system's accident reports to compile the requested data, which were provided in an electronic format to obviate the need for data entry. The database provided to CUTR contained a total of 1,501 occurrence records. The system's safety coordinator also supplied a code sheet with the electronic data in order to assist with the correct identification and definition of the different geography and collision types included in the data. These had been included in the database as numerical codes instead of actual descriptions.

To ensure the privacy and anonymity of the HART operators, in the database provided to CUTR, each occurrence record included a payroll number as the only means to identify the driver involved. Subsequently, a separate data sheet was requested that contained hire and termination dates by payroll number for all HART operators included in the analysis. Using payroll numbers, then, a driver tenure variable (i.e., years of experience based on the difference between the date of the crash and the driver's hire date) was able to be calculated for each of the occurrence records in the database. For purposes of this analysis, only operators who were hired prior to the provision of the refresher training course will be included.

Following are two sections documenting the results of the analyses for this case study. The first section presents some basic frequency distribution results that describe a selection of general characteristics of all of the crashes included in the analysis without consideration for the effects of the refresher training course. Typically, this information is useful in analyzing the potential causes of and/or reasons for crashes. It also can help guide the formulation of training procedures and other safety-related strategies to decrease overall crash occurrence. The second section discusses the systemwide effects of the retraining campaign, with specific attention given to pre- and post-implementation distributions of various occurrence characteristics. This section also details a more in-depth analysis of operator experience level, including an analysis of pre- and post-retraining crash rates in comparison to operator exposure and experience.

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[1] It should be noted that the occurrence database provided by HART included records only through November 15, 1999. Therefore, the study period is actually 37.5 months in length. This has been accounted for in subsequent analyses, as necessary.

General Occurrence Characteristics

Using SPSS, frequency distributions were compiled for each of the variables included in the occurrence database provided by HART. For purposes of this case study, it is important to recognize that only crash (i.e., occurrences involving a collision of some sort) data were included in the analyses. It is not believed that an operator training course will have a significant impact on the occurrence of passenger-related "incidents" (e.g., a passenger slip-and-fall), therefore incidents have been excluded from these analyses. As a result, a total of 823 crash occurrence records were analyzed. The results of the frequency distributions are presented and discussed in this section. This information is useful in setting the context for overall crash occurrence at HART during the study period.

Crash Occurrence by Month

In Table 1, the combined frequency distribution for the months during which the study period crashes occurred is presented. For example, the 37.5-month study period (as noted previously, only a half month's worth of data was provided for November 1999) included three months of January (1997, 1998, and 1999), therefore, the number of crashes that occurred in each were combined to total 55, or 6.7 percent of the 823 total crashes during this time span. The last column in the table reflects the per-month crash averages to facilitate comparison of monthly crash occurrence.

It is evident from the information presented in the table that July has the highest crash occurrence, with an average of nearly 28 crashes per month. Only October has a higher overall frequency of crashes (85 versus 83 for July), but the study period included four months of October (1996, 1997, 1998, and 1999) compared to only three months of July. September has the lowest average crash occurrence rate of all the months: 15.8 crashes per month. A comparison of each month's average crash rate to the overall average of 21.7 crashes per month found that none of the months produced a statistically different crash rate.

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Table 1
Combined Frequency Distribution for Monthly Crash Occurrence

Month	Combined Frequency	Percent Distribution	Average Frequency
January	55	6.7	18.3
February	73	8.9	24.3
March	71	8.6	23.7
April	60	7.3	20.0
May	76	9.2	25.3
June	71	8.6	23.7
July	83	10.1	27.7
August	71	8.6	23.7
September	51	6.2	17.0
October	85	10.3	21.2
November	63	7.7	18.0
December	64	7.8	21.3
Total	**823**	**100.0**	**21.9**

Crash Occurrence by Day of Week

Similar to the per-month analysis presented previously, Table 2 includes the day of week analysis for crash occurrence. The table illustrates the combined frequency distributions by day of week for all of the study period crashes. The 1,141 days of the study period included 163 days for each day of the week. Therefore, considering Monday as an example, a total of 133 crashes (or 16.2 percent of the 823 total collision occurrences during this time span) occurred on the 163 Mondays in the study period. This results in an average crash occurrence rate of 0.82 for each Monday included in the analysis. The last column in the table presents the daily crash averages for each weekday, as well as for the entire study period.

The data in the table indicate that Tuesdays have the highest crash occurrence, with an average of 1.01 daily crashes. Tuesdays also have the highest overall frequency of crashes (164 crashes), followed by Thursday, Friday, and Wednesday. Typically, Tuesday through Thursday are the busiest travel days of the week – days during which the most traffic is on the roads. This factor significantly increases the exposure rate for transit vehicles traveling on these days. Conversely, Sundays have the lowest average crash occurrence rate (0.24 daily crashes) of all the weekdays, followed closely by Saturdays (0.37 daily crashes). Somewhat lower levels of weekend transit service help to decrease exposure and, therefore, collision occurrence.

Table 2
Frequency Distribution for Day of Week Crash Occurred

Day of Week	Frequency	Percent Distribution	Average Frequency
Monday	133	16.2	0.82
Tuesday	164	19.9	1.01
Wednesday	141	17.1	0.86
Thursday	143	17.4	0.88
Friday	142	17.3	0.87
Saturday	60	7.3	0.37
Sunday	40	4.9	0.24
Total	**823**	**100.0**	**0.72**

Crash Occurrence by Time of Day

Table 3 presents the frequency distribution for the various times of the day that the crashes occurred. HART operates between 4:30 a.m. and 11:15 p.m. during weekdays. On weekends, HART operates between 6:00 a.m. to 3:30 a.m. The time periods during which the most crashes occurred are in the p.m. rush period from 3:00 - 6:00 p.m. Combined this time period represents nearly 25 percent of total crash occurrence. In general, the crash frequencies increase gradually throughout the day beginning in the a.m. rush hour. A decline in crash frequency occurs during the lunch hour and a more significant decrease occurs after 6:00 p.m.

Table 3
Frequency Distribution for Time of Day Crash Occurred

Time of Day	Frequency	Percent Distribution
6 to 6:59 AM	46	5.6
7 to 7:59 AM	51	6.2
8 to 8:59 AM	47	5.7
9 to 9:59 AM	58	7.0
10 to 10:59 AM	45	5.5
11 to 11:59 AM	56	6.8
12 to 12:59 PM	27	3.3
1 to 1:59 PM	63	7.6
2 to 2:59 PM	49	6.0
3 to 3:59 PM	59	7.2
4 to 4:59 PM	62	7.5
5 to 5:59 PM	81	9.8
6 to 6:59 PM	33	4.0
7 to 7:59 PM	29	3.5
8 to 8:59 PM	28	3.4
9 to 9:59 PM	9	1.1
10 to 10:59 PM	10	1.2
11 to 11:59 PM	2	0.2
Subtotal	755	91.7
Missing	68	8.3
Total	**823**	**100.0**

Crash Occurrence by Type of Weather

The frequency distribution for the weather conditions at the time of each of the study period crashes is contained in Table 4. More than three-quarters of the crashes for which weather conditions were reported occurred on clear days (77.6 percent). Only 8.5 percent and 5.7 percent of the crashes occurred on rainy days or in darkness, respectively. Approximately three percent of the study period crashes did not have weather conditions noted in their database records.

Table 4
Frequency Distribution for Type of Weather When Crash Occurred

Weather	Frequency	Percent Distribution
Clear	639	77.6
Fog	3	0.4
Rain	70	8.5
Dawn	20	2.4
Dusk	16	1.9
Dark/Night	47	5.7
Subtotal	795	96.6
Missing	28	3.4
Total	**823**	**100.0**

Crash Occurrence by Route

The frequency distribution for the routes on which the crashes for the entire study period occurred is presented in Table 5. The two routes with the most collision occurrences are Route 2 (7.3 percent of study period collision crashes) and Route 7 (6.0 percent). These are two of the longest routes in the system, traversing nearly the entire northern portion of the county in a north-south direction, and operating a significant amount of revenue miles. Both routes also operate primarily along urban roadways: Route 2 operates along Nebraska Avenue and Route 7 operates generally along North Boulevard.

Table 5 also provides the Z-statistics for the analysis of crash occurrence by route. High Z-statistics, 1.40 or higher, can be used to identify routes that are more prone to crash occurrence relative to the other routes in the system. This information can help identify potential problem routes within the system.

The routes with a higher proclivity for collision occurrence, as identified in Table 5, include Routes 1, 2, 7, 8, 12, and 34. Based on the results of this analysis, it may be prudent for HART staff to investigate these routes further to identify the reason(s) behind this finding. Factors that may be impacting these specific routes include traffic congestion, roadway geometry and condition, and/or operator characteristics (e.g., experience level, safety record, etc.).

Table 5
Frequency Distribution for Route Where Crash Occurred

Route	Frequency	% Distribution	Z-Statistic	Route	Frequency	% Distribution	Z-Statistic
1	42	5.1	1.8390444	27	2	0.2	-0.832829
2	60	7.3	3.0413873	28	3	0.4	-0.766032
3	14	1.7	-0.031267	30	18	2.2	0.2359204
4	10	1.2	-0.298454	31	6	0.7	-0.565642
5	27	3.3	0.8370919	32	28	3.4	0.9038887
6	26	3.2	0.770295	33	3	0.4	-0.766032
7	49	6.0	2.3066222	34	39	4.7	1.6386539
8	37	4.5	1.5050602	36	27	3.3	0.8370919
9	20	2.4	0.3695141	37	2	0.2	-0.832829
10	14	1.7	-0.031267	38	10	1.2	-0.298454
11	12	1.4	-0.164861	39	3	0.4	-0.766032
12	38	4.6	1.571857	41	11	1.3	-0.231657
14	16	1.9	0.1023267	44	1	0.1	-0.899626
15	22	2.7	0.5031077	46	5	0.6	-0.632438
16	13	1.6	-0.098064	50	4	0.5	-0.699235
17	12	1.4	-0.164861	54	2	0.2	-0.832829
18	32	3.9	1.171076	56	1	0.1	-0.899626
19	33	4.0	1.2378729	68	1	0.1	-0.899626
20	4	0.5	-0.699235	84	1	0.1	-0.899626
21	4	0.5	-0.699235	85	1	0.1	-0.899626
22	2	0.2	-0.832829	90	3	0.4	-0.766032
23	2	0.2	-0.832829	96	4	0.5	-0.699235
25	1	0.1	-0.899626	200	14	1.7	-0.031267
26	1	0.1	-0.899626	Missing	143	18.7	---
				Total	823	100.0	---

Each of the "trouble spot" routes (i.e., those shown in bold in Table 5) was examined for its types of involvements. Rear end collisions were prevalent on Routes 1 (19 percent of all collision crashes occurring on the route), 2 (37 percent), 7 (22 percent), and 12 (34 percent). Road geometry often can play a role in the occurrence of rear end collisions. For example, it is possible that a vehicle can rear end a slowing or stopped bus if the vehicle's driver is operating in an inattentive, aggressive, and/or negligent manner and the roadway does not offer a shoulder or other opportunity for recovery. It is logical, then, that buses operating along roadways without shoulders or multiple lanes (or with heavy volumes of traffic) are more susceptible to rear end impacts. These four routes with a higher incidence of rear end collisions simply may be operating in route environments that cultivate this type of impact.

An examination of Route 34 indicates that this route displays a higher tendency for sideswipe crashes, with this type of impact accounting for 46 percent of all crashes on the route. HART staff

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may want to consider reviewing the roadway geometry of this route to identify any segments with narrow driving lanes, which typically can lead to the increased probability of sideswipes. Edge of pavement obstructions, such as trees or signage, may also promote this type of impact due to the buses having to operate closer to the center of the driving lane. All of these routes also have high collision rates with fixed objects; however, Route 8 has a particular issue with this type of impact. A total of 35 percent of all the crashes on Route 8 involve collisions with fixed objects.

Crash Occurrence by Geographic Area

As shown in Table 6, over 70 percent of all transit vehicle crashes occurred in the northern region of the service area. The northwest region alone accounted for a quarter of all crashes. The northeast region accounted for almost half of the service area's crashes. These two areas should be identified as trouble spots. The least number of crashes were found in the southeast, with only 3.0 percent of all crashes.

Table 6
Frequency Distribution for Geographic Area in which Crash Occurred

Geographic Area	Frequency	Percent Distribution
Northwest County	214	26.0
Northeast County	381	46.3
Southwest County	74	9.0
Southeast County	25	3.0
Downtown Tampa	102	12.4
Missing	27	3.3
Total	**823**	**100.0**

In order to more accurately portray the geographical area in which crashes occur, one would plot and graph the crash occurrences at a smaller scale so as to pinpoint the crash location at the intersection level. This would allow for identifying areas requiring more detailed analyses to identify route, road geometry, or site issues that may be contributing to the higher levels of crash occurrence. As an example, Figure 1 plots the 60 crashes that occurred on Route 2 during the time frame of this analysis. As can be seen from this figure, the two intersections with the highest density of crash occurrence are Nebraska Avenue and Busch Boulevard, and Nebraska Avenue and Fletcher Avenue. Both of these are very busy, major intersections. It should be noted that the few

crashes that are not located along the route may have occurred while the bus was deadheading to or from the operations facility.

Figure 1
Map Plot of the Geographic Locations of Route 2 Crashes

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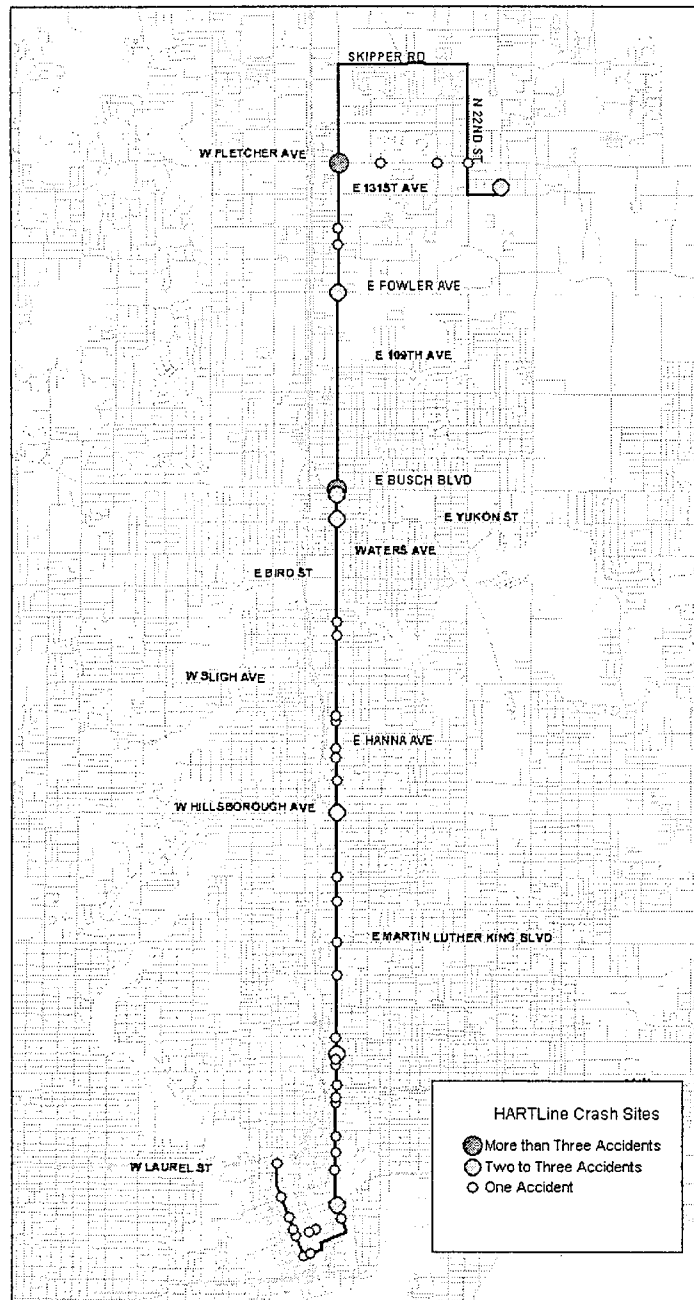
Crash Occurrence by Roadway Type

Table 7 includes the frequency distribution for the types of roadways on which the study period crashes occurred. For the most part, the majority of crashes occurred on suburban roadways classified as "commercial" (59.8 percent of the total) The next largest segment of crashes occurred on HART property (12.9 percent). In addition, 3.2 percent of the crashes that occurred during the study period took place on a highway facility that either could not be properly classified or was not reported. Very particular attention should be given by HART staff to those crashes occurring on HART property, which is a controlled environment in which **all** crashes would be deemed preventable.

Table 7
Frequency Distribution for Type of Roadway on which Crash Occurred

Roadway Type	Frequency	Percent Distribution
Rural	18	2.2
Urban (non-Suburb)	61	7.4
Suburb - Residential	66	8.0
Suburb - Commercial	492	59.8
Expressway/Interstate	19	2.3
Mall/Shopping Center	26	3.2
Other Private Property	4	0.5
HART Property	106	12.9
Park-and-Ride Facility	5	0.6
Missing/Not Determined	26	3.2
Total	**823**	**100.0**

Crash Occurrence by Route Type

In Table 8, the frequency distribution for the various route types on which the study period crashes occurred is shown. According to the data presented, the vast majority of crashes occurred on local routes (79.8 percent of all crashes). This result is logical given that local routes make up the significant majority of HART's service routes. The next highest crash occurrence distribution percentage is only 7.7 percent, for out-of-service vehicles involved in a crash on HART property. A total of 26 crashes (3.2 percent of total) in the database did not have route type recorded.

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Combining the results of the previous three analyses (i.e., geographic area, highway type, and route type) using the cross-tabulation function in SPSS, one finds that the majority of HART's crashes during the study period occurred in the northern portion of HART's service area (north of Kennedy Boulevard) on local routes operating along suburban commercial roadways. This combination of results accounts for 42.6 percent (351 of 823) of all crashes in the study period's data sample.

Table 8
Frequency Distribution for Type of Route on which Crash Occurred

Route Type	Frequency	Percent Distribution
Local	657	79.8
Express	22	2.7
Charter	4	0.5
Roadcall	7	0.9
Maintenance Check (Shelters)	8	1.0
Deadhead	16	1.9
Out-of-Service on Property	63	7.7
Staff Vehicle	18	2.2
Standby	2	0.2
Missing/Not Determined	26	3.2
Total	**823**	**100.0**

Crash Occurrence by Type of Involvement

The frequency distribution for the type of involvement for the study period crash occurrences is presented in Table 9. As evidenced in the table, the majority of these crashes involved a motor vehicle (67.7 percent of study period collision crashes). The next highest incident type involved collisions with fixed objects (19.2 percent). Together, these two involvement types accounted for nearly 87 percent of HART's total collision crashes for the study period. The "miscellaneous" category includes involvements occurring due to the mechanical failure of the bus, the bus leaving the roadway, and other collisions not otherwise classified.

It should be recognized that occurrences involving "another HART vehicle" mostly happen on HART property (e.g., maintenance facility, etc.). One factor influencing this type of involvement is the fact that, besides regular drivers, individuals operating the buses in these instances also include mechanics and fuelers. Their on-site occurrences are included in HART's accident reporting, too.

Table 9
Frequency Distribution for Type of Involvement

Type of Involvement	Frequency	Percent Distribution
Fixed Object	158	19.2
Motor Vehicle	557	67.7
Parked Vehicle	7	0.9
Pedestrian	32	3.9
Another HART Vehicle	33	4.0
Miscellaneous	36	4.4
Total	**823**	**100.0**

Crash Occurrence by Impact Dynamics

The frequency distribution for the particular dynamics of the impacts of the study period crash occurrences is presented in Table 10. The data in the table indicate that rear end impacts where the bus was hit by another vehicle (26.4 percent of all collision impacts involving a bus and another motor vehicle) had the highest frequency of occurrence. The second most frequent dynamic of impact was broadside (16.9 percent) where the bus was hit on the side by another vehicle.

Table 10
Frequency Distribution for Occurrence Impact Dynamics

Impact Dynamics	Frequency	Percent Distribution
Head On	0	0.0
Turning Left	44	7.9
Turning Right	17	3.1
Vehicle Broadsides Bus	94	16.9
Bus Broadsides Vehicle	30	5.4
Vehicle Rear Ends Bus	147	26.4
Bus Rear Ends Vehicle	43	7.7
Side Swipe	58	10.4
Loading Zone Entry/Exit	38	6.8
Bus Cut Off by Vehicle	33	5.9
Other	53	9.5
Total	**557**	**100.0**

Crash Occurrence by Identified Preventability Status

The frequency distribution for the preventability status (i.e., whether a crash is preventable or non-preventable) of the study period's crashes is presented in Table 11. Since HART utilizes several classifications to categorize its crashes besides the "preventable" and "non-preventable" designations[2], and due to the presence of a large number of missing data, it was necessary to calculate a percent distribution for this variable based on "valid" data (i.e., just the preventable and non-preventable crashes). According to this distribution, 68.6 percent of the HART crashes that occurred during the study period were classified as non-preventable by the system.

Table 11
Frequency Distribution for Identified Preventability Status of Crashes

Preventability Status	Frequency	Percent Distribution	Valid % Distribution
Preventable	207	25.2	31.4
Non-Preventable	453	55.0	68.6
Other	30	3.6	---
Missing	133	16.2	---
Total	**823**	**100.0**	**100.0**

Crash Occurrence By Years of Operator Experience

HART provided hire dates for all of its operators involved in the study period occurrences. These dates were utilized to calculate the operators' levels of experience (in terms of years) at the time of each occurrence. For purposes of this analysis, each occurrence is considered independently from one another and each operator is assumed to have received the same refresher training.

Table 12 details three separate frequency distributions related to operator experience. The first two data columns present the distribution of all collision occurrences by the operator experience categories. The second two columns are similar to the first two except that they include the distribution for preventable crashes only. The final column illustrates the distribution of HART operators by level of experience based on 1998 employee data. This information, a proxy for operator exposure, is useful in detailing the experience level breakdown of HART operators (i.e.,

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[2] The "Other" classifications utilized by HART include: "not to be heard until next month," "on hold," and "under review."

12.1 percent of HART's drivers had less than 1 year of experience in 1998). It is also helpful in analyzing the relationship between crash occurrence within each experience category and the proportion of drivers in each category. For example, drivers with less than one year of experience accounted for 12.1 percent of HART's driver population in 1998; however, this group was responsible for 22.8 percent of all crashes and 35.3 percent of preventable crashes. It is important to note that this type of analysis is primarily useful for identifying particular groups of drivers that may be having issues related to crash occurrence. A better technique would be to utilize a measure of exposure, such as using either miles or hours of service between crashes to calculate crash occurrence by experience category. This technique is utilized in the pre- and post-training section to further analyze crash occurrence rates by operator experience level.

One important question that this analysis raises is whether it is more important and/or cost effective to re-train those groups of drivers that have the highest crash occurrence rates, or re-train those groups with significantly disproportionate crash occurrence rates in comparison to their proportion of the overall driver population.

Table 12
Frequency Distribution of Crashes and Operators by Operator Experience

Years of Experience at HART	Frequency (All)	Valid % Distribution	Frequency (Preventable)	Valid % Distribution	Operator % Distribution (1998)
Less than 1 year	154	22.8	59	35.3	12.1
1 year	66	9.8	20	12.0	11.0
2 years	35	5.2	11	6.6	4.4
3 years	24	3.6	4	2.4	1.8
4 years	23	3.4	7	4.2	1.1
5 years	22	3.3	2	1.2	4.0
6 years	12	1.8	2	1.2	1.8
7 years	18	2.7	3	1.8	2.2
8 years	21	3.1	4	2.4	1.5
9 years	19	2.8	2	1.2	2.6
10 years	30	4.4	8	4.8	5.9
11 years	32	4.7	5	3.0	1.8
12 years	37	5.5	7	4.2	6.6
13 years	31	4.6	8	4.8	5.5
14 years	37	5.5	0	0.0	11.0
15 years	27	4.0	8	4.8	7.0
16 years	26	3.9	6	3.6	4.0
17 years	18	2.7	0	0.0	4.8
18 years	10	1.5	3	1.8	4.0
19 years	9	1.3	3	1.8	2.2
20 years	1	0.1	1	0.6	0.7
21 or more years	23	3.4	4	2.4	3.7
Missing	148	---	40	---	---
Total	**823**	**100.0**	**207**	**100.0**	**100.0**

Summary of General Occurrence Characteristics

Based on a review of the frequency distributions completed for selected occurrence characteristics from the occurrence database provided by HART, it was determined that a "typical" crash during the study period occurred:

- during the month of May;

- on a Tuesday;
- between the hours of 5:00-5:59 p.m.;
- under clear weather conditions;
- on Route 2;
- on a suburban commercial roadway;
- on a local bus route;
- involving another motor vehicle; ·
- as a rear end collision with the bus being hit from behind;
- as a non-preventable occurrence; and
- involving an operator with less than one year of experience.

Analysis of the Impact of HART Refresher Training Course

To analyze the impact of HART's refresher training course on crash occurrence, the database utilized in the previous frequency analyses was subdivided into two separate databases so that pre- and post-training crash occurrence could be compared. To establish these databases, first, the data for those months during which the training was being conducted (i.e., May to July 1998) were extracted. Then, the remaining months of available data were pared down and separated into two 12-month periods: one for pre-training (May 1997 to April 1998) and one for post-training (August 1998 to July 1999). Even though the creation of the two 12-month databases excluded additional months of crash data that HART provided originally (as noted previously, a total of 37.5 month's of data were included in HART's database), this process was necessary to ensure that the two analysis periods were equal in terms of length (so that the data would not need to be normalized for period duration) and that the included months in each were homogeneous between periods. Homogeneity of the analysis periods is important because of potential annual seasonal variations in crash occurrence – this is why a 12-month analysis period was ultimately selected.

As in all previous analyses, only crash data have been reviewed for purposes of this evaluation. To this end, only crash records with a valid collision code were included. It is also important to note that the crash records had to be filtered further for specific operator characteristics, as well. That is, only crash records were included where the involved driver either went through the refresher training course or was newly hired after the refresher training course was conducted. Finally, the filtering process resulted in a pre-training database of 265 collision crash records and a post-training database of 259 records. The following sections discuss the impact results for selected variables related to crash occurrence before and after the refresher training for HART operators.

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Impact of Training on Crash Occurrence by Month

Table 13 presents comparative data for monthly crashes for the pre- and post-training periods. As shown, the month of April experienced a 36.8 percent increase in crash occurrence after the refresher training course was conducted. Conversely, the month of January indicated a 43.5 percent decline in crash occurrence. Overall, average monthly crash occurrence decreased 2.3 percent from 22.1 average monthly crashes before the training to 21.6 average monthly crashes after the training.

Table 13
Change in Crash Occurrence by Month

Month	Pre-Training	Post-Training	Percent Change
January	23	13	-43.5
February	26	25	-3.8
March	26	23	-11.5
April	19	26	36.8
May	20	23	15.0
June	23	29	26.1
July	29	29	0.0
August	20	15	-25.0
September	17	18	5.9
October	17	21	23.5
November	23	16	-30.4
December	22	21	-4.5
Total	**22.1**	**21.6**	**-2.3**

Impact of Training on Crash Occurrence by Type of Involvement

Table 14 examines the change in crash occurrence between the pre- and post-training periods by the various types of involvement. While many of the different types of involvement show significant percentage changes, it also is important for analysis purposes to consider the relationship between the percentage change and the scale of the actual crash data. For example, the "another HART vehicle" involvement category showed a 567 percent increase from the pre- to post-training periods. The actual change in terms of actual crash occurrence, however, went from 3 to 20 crashes between the periods – a difference of 17 crashes. Conversely, a much smaller percentage change

(a 13.8 percent decline) occurred for the motor vehicle involvement category, but its difference in pre- and post-training crash occurrence was 26 total crashes.

According to the data in the table, it is evident that involvements with other motor vehicles, parked vehicles, and pedestrians all decreased between the two analysis periods, while involvements with fixed objects and other HART vehicles both increased. Overall, total crash occurrence decreased 2.3 percent between the two analysis periods.

As noted previously in the General Occurrence Characteristics section, involvements with "another HART vehicle" typically occur on site at HART's maintenance facility. These occurrences may happen with either a regular driver, a mechanic, or a fueler operating the bus(es) involved. Interestingly, to help alleviate these type of involvements, in the last six months HART has begun holding special three-week training classes for any other personnel (besides regular drivers) that operate the buses as part of their jobs.

Table 14
Change in Crash Occurrence by Type of Involvement

Type of Involvement	Pre-Training	Post-Training	Percent Change
Fixed Object	51	58	13.7
Motor Vehicle	188	162	-13.8
Parked Vehicle	5	0	-100.0
Pedestrian	15	8	-46.7
Another HART Vehicle	3	20	566.7
Miscellaneous	3	11	266.7
Total	**265**	**259**	**-2.3**

Impact of Training on Crash Occurrence by Impact Dynamics

Table 15 presents the change in crash occurrence between the pre- and post-training periods by the impact dynamics of the crashes. The table's data indicate that there was a 200 percent increase in "loading zone entry/exit" impacts (i.e., crashes where the bus hit or was hit by another vehicle as it entered or exited from a loading zone) and an 87 percent decline in crashes where the bus broadsided another vehicle. The highest absolute change in crash occurrence data, however, involved rear end crashes where the bus was hit from behind, which dropped from 57 to 40 total crashes between the two analysis periods.

Table 15
Change in Crash Occurrence by Impact Dynamics

Impact Dynamics	Pre-Training	Post-Training	Percent Change
Head On	0	0	n/a
Turning Left	10	21	110.0
Turning Right	3	6	100.0
Vehicle Broadsides Bus	28	29	3.6
Bus Broadsides Vehicle	15	2	-86.7
Vehicle Rear Ends Bus	57	40	-29.8
Bus Rear Ends Vehicle	18	10	-44.4
Side Swipe	18	22	22.2
Loading Zone Entry/Exit	4	12	200.0
Bus Cut Off by Vehicle	14	10	-28.6
Other	21	10	-52.4
Total	**188**	**162**	**-13.8**

Impact of Training on Crash Occurrence by Identified Preventability Status

The analysis of pre- and post-training collision occurrences in relation to their preventability status indicates that preventable crash occurrence increased approximately 51 percent, while the average number of non-preventable crashes per month declined almost 13 percent. The results of this analysis are presented in Table 16.

Table 16
Change in Crash Occurrence by Identified Preventability Status

Preventability Status	Pre-Training	Post-Training	Percent Change
Preventable	59	89	50.8
Non-Preventable	165	144	-12.7
Other	3	21	600.0
Missing	38	5	-86.8
Total	**265**	**259**	**-2.3**

Impact of Training on Crash Occurrence by Years of Operator Experience

The operator experience cohorts utilized previously in the frequency analysis section were also used to analyze the before and after effects of the systemwide refresher training course on each

operator group. According to NTD data, the total number of HART operators increased 10.2 percent between the 1997 and 1999 fiscal years. Table 17 illustrates the changes in crash occurrence for each year of operator experience. According to the data, the range of operator experience levels with the greatest increase in crash occurrence was drivers with less than three years of experience. This group's total number of crashes increased from 58 crashes before training to 118 crashes after training, an increase of 103 percent.

The other range of operator experience levels that stands out from the table is that of drivers with between six and nine years of experience. This particular group's average monthly crash rate decreased a total of 60 percent, from 25 total crashes before training to 10 total crashes after training.

Table 17
Change in Crash Occurrence by Operator Experience

Years of Experience at HART	Pre-Training	Post-Training	Percent Change
Less than 1 year	34	74	117.6
1 year	18	32	77.8
2 years	6	12	100.0
3 years	9	7	-22.2
4 years	19	1	-94.7
5 years	4	14	250.0
6 years	5	2	-60.0
7 years	6	4	-33.3
8 years	4	2	-50.0
9 years	10	2	-80.0
10 years	8	9	12.5
11 years	10	7	-30.0
12 years	15	7	-53.3
13 years	11	11	0.0
14 years	6	15	150.0
15 years	13	6	-53.8
16 years	6	11	83.3
17 years	1	10	900.0
18 years	5	3	-40.0
19 years	0	7	n/a
20 years	0	1	n/a
21 or more years	7	8	14.3
Missing	68	14	-79.4
Total	**265**	**259**	**-2.3**

Table 18 presents a similar analysis to that shown in Table 17, except that only preventable crashes are analyzed. From the data in this table, it is evident that the group of drivers with less than four years of experience indicated the most significant change in the occurrence of preventable crashes. This group had an increase of 235 percent in total preventable crashes between the two analysis periods, from 17 crashes before training to 57 crashes after training.

Table 18
Change in Preventable Crash Occurrence by Operator Experience

Years of Experience at HART	Pre-Training	Post-Training	Percent Change
Less than 1 year	8	36	350.0
1 year	6	14	133.3
2 years	2	4	100.0
3 years	1	3	200.0
4 years	6	0	-100.0
5 years	0	1	n/a
6 years	0	0	n/a
7 years	3	0	-100.0
8 years	2	0	-100.0
9 years	0	1	n/a
10 years	0	6	n/a
11 years	1	1	0.0
12 years	1	3	200.0
13 years	1	6	500.0
14 years	0	0	n/a
15 years	4	1	-75.0
16 years	2	2	0.0
17 years	0	0	n/a
18 years	1	1	0.0
19 years	0	2	n/a
20 years	0	1	n/a
21 or more years	2	1	-50.0
Missing	19	6	-68.4
Total	**59**	**89**	**50.8**

Impact of Training on Crash Occurrence Versus Exposure

To further investigate the effects of the training it is recommended that a system also take into account the exposure each driver group had during the study. Exposure could be measured by the number of miles or hours worked by each operator during the pre- and post-training study periods.

To assist in this effort, HART staff was asked to provide operator platform hours by employee number so that total platform hours could be calculated for each of the driver experience levels (i.e., by years of experience). Unfortunately, HART was only able to provide total paid hours for its operators. Though an attempt was made to utilize this information as a proxy, it was determined that, due to the fact that the paid hours included overtime and other potential premiums, the total hours did not appear reasonable compared to reported National Transit Database revenue hours of service. Therefore, CUTR elected not to utilize this information to account for exposure.

Instead, it was decided to utilize revenue hours of service to measure exposure. National Transit Database information for the 1997, 1998, and 1999 fiscal years was used to calculate estimates for HART's total revenue hours for the pre- and post-training study periods. As shown in Table 19, between the two periods, revenue hours increased 2 percent from 414,290 hours to 422,698 revenue hours. This table also includes HART's total crashes and total preventable crashes, which have been discussed previously in this section.

Accounting for exposure, then, the number of hours between crashes increased 4.4 percent. This is a positive outcome since it suggests that more hours of service were able to provided between crashes after the training period. However, due to the significant overall increase in preventable crashes between the two study periods (50.8 percent), and accounting for exposure, the number of hours between preventable crashes declined 32.4 percent.

Table 19
Changes in Crashes, Preventable Crashes, Service Hours, and Hours Between Crashes

Variables	Pre-Training	Post-Training	Percent Change
Total Crashes	265	259	-2.3
Total Preventable Crashes	59	89	50.8
Revenue Hours	414,290	422,698	2.0
Revenue Hours Between Crashes	1,563	1,632	4.4
Revenue Hours Between Preventable Crashes	7,022	4,749	-32.4

Impact of Training on Crash Cost

The cost of a collision occurrence, which is strictly an "accounting" cost, is the unreimbursed amount paid by HART to repair damage to the HART vehicle and the other vehicles and/or objects involved in the crash, as well as payments for personal injuries to bus patrons and/or the other

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parties involved in the crash. What is not included are any "economic" costs, such as lost revenue due to the bus not being in service or the driver being out of work due to the crash.

Based on an analysis of crash cost data provided by HART, CUTR derived an average cost per collision occurrence of $168.99. In addition, average costs per collision occurrence also were calculated for preventable crashes ($106.89) and non-preventable crashes ($233.62). Using this information, and the change in crash occurrence by preventability status between the pre- and post-training periods, a total savings of approximately $5,200 can be estimated for HART.[3] This information is important for comparing the potential savings in any crash reduction to the total cost for providing the refresher training to determine the cost versus benefit of such an endeavor.

Summary of Impact of HART Refresher Training Course

Based on the analyses completed in this section, key findings on the impacts of HART's refresher training course are as follows:

- "hitting another HART vehicle" as a type of involvement increased 566 percent between the pre- and post-training periods;
- collisions involving another motor vehicle (non-HART) decreased 14 percent as a type of involvement;
- the impact dynamic with the greatest increase between the study periods was "entering/exiting loading zone" (200 percent);
- the impact dynamic "bus broadsides vehicle" decreased 87 percent between study periods;
- collision occurrences classified as being "preventable" increased 51 percent after implementation of the refresher training course;
- operators with less than three years of experience indicated a 103 percent increase in collision occurrence;
- operators with six to nine years of experience indicated a decline of 60 percent in collision occurrence;
- operators with less than four years of experience indicated an increase of 235 percent in preventable collision occurrence;

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[3] It should be noted that the seemingly low per-collision cost figures were reviewed and verified by HART staff. It was indicated that the cost averages are lower than what might be expected because a majority of HART's collision occurrences either do not have a cost associated with them or the resulting costs have been fully refunded.

- revenue hours between collision occurrences increased more than 4 percent from 1,563 to 1,632 hours per crash;
- revenue hours between preventable collision occurrences decreased more than 32 percent from 7,022 to 4,749 hours per preventable crash; and
- the total cost savings attributed to the refresher training program is estimated to be approximately $5,200.

In summary, overall, the evaluation does indicate that crash occurrence declined after conduct of the refresher training course, both in absolute terms (2.3 percent decline in total collision occurrences) and when considering exposure (revenue hours between crashes increased 4.4 percent between the pre- and post-training study periods). However, the discrete analyses contained in this case study show that there are other factors to consider than just this simple conclusion. For example, while total collision occurrences decreased, preventable crashes actually increased more than 50 percent between the two study periods. This may be an indication that the refresher training course did not emphasize training that would lead to the reduction of this type of crash occurrence. Specific within the category of preventable crashes, training modules may need to be developed that address the reduction of crashes involving fixed objects and crashes that occur within the HART operations facility.

Another factor that must be accounted for is the influence that the significant influx of new drivers at HART had on the pre- and post-training analyses. The driver information provided by HART showed that, during the pre-training period, approximately 30 percent of HART's operators had less than three years of experience; during the post-training period, the distribution of these less experienced drivers increased to 44 percent. According to HART staff, large groups of new drivers have been hired each year, beginning in 1998 – the same year that the refresher training was conducted. The impact of these new, inexperienced drivers is very noticeable. For example, prior to the course being implemented, drivers with less than three years of experience accounted for 22 percent of all collision occurrences and 27 percent of all preventable collision occurrences. However, after the refresher training course, these proportions increased to 46 percent and 61 percent, respectively. Nevertheless, the data show that the refresher training course did have a positive effect on more experienced operators (i.e., those with more than fours years of experience). Therefore, it may be more beneficial to offer this particular training to the more experienced drivers and to develop a different course or provide additional and/or different course modules to the less experienced operators.

In addition to any data-related conclusions that can be drawn from these analyses, it is also important to learn from the process of the evaluation, itself. For example, an important part of the evaluation would be to compare the fully-allocated cost of providing the refresher training course versus the cost savings realized from any reduction in crash occurrence. This particular comparison could not be made for this case study because of the unavailability of appropriate cost data. Therefore, for purposes of further and future evaluation, it is important for HART to maintain the full cost of the program including the costs for the drivers attending the training, the drivers replacing those operators in the field (assuming that the drivers are not required to attend training during off hours, in which case they may receive overtime pay instead) , and the cost of the trainer and any training materials. Conversely, it is equally important to collect and maintain the fully-allocated HART-specific costs attributed to each collision occurrence in the database, as well. In fact, it is recommended that all safety-related campaigns, whether capital or training, develop an evaluation process prior to the initiation of the campaign.

LYNX CASE STUDY: REAR-END HIGH DENSITY LIGHTS

LYNX is an independent authority that provides fixed-route motorbus, demand response, and vanpool services to a three-county region that includes Orange, Seminole, and Osceola Counties. The system also coordinates a five-county regional ridesharing assistance program and transportation disadvantaged services for the region. According to FY 1999 National Transit Database information (the most recent year for which validated NTD data are available), LYNX's service area covers more than 2,500 square miles and has a population of almost 1.4 million persons. Fixed-route motorbus service is provided seven days per week using a peak fleet of 168 vehicles. LYNX provided a total of 19.8 million passenger trips and more than 10.4 million revenue miles of service in FY 1999. Given LYNX's peak vehicle fleet and the amount of service miles it operates, it was determined that the system's size fit the necessary criteria for conduct of a statistically valid crash analysis.

LYNX purchased and installed rear-end high density LED lights (which replaced the buses' original brake and turn signal/emergency flasher light assemblies) on the majority of its bus fleet during the time period from March to December 1998. Therefore, the objective of this case study is to examine the systemwide effects that this vehicle safety improvement has on crash occurrence. In particular, this evaluation is especially interested in the impact that the high density lights have on the occurrence of rear end collisions. The rear-end light configuration of a typical LYNX bus is shown in Figure 3. The two light assemblies at the lower corners of the bus consist of two red brake lights at the top and bottom of each assembly (highlighted by the white arrows on the right side of the

figure) and one amber light in the middle of each assembly (highlighted by the white arrow on the left side of the figure) that serves as the turn signal indicator and emergency flasher. The standard bulb-and-lens cover fixtures in these particular assemblies were replaced with high density LED lights. The benefit of the new fixtures is that the entire surface of the light (i.e., the lens cover area) illuminates rather than a single bulb inside the fixture, making the lights significantly brighter and easier to see for motorists following the vehicle.

Figure 2
High Density Lights on the Back of a LYNX Bus
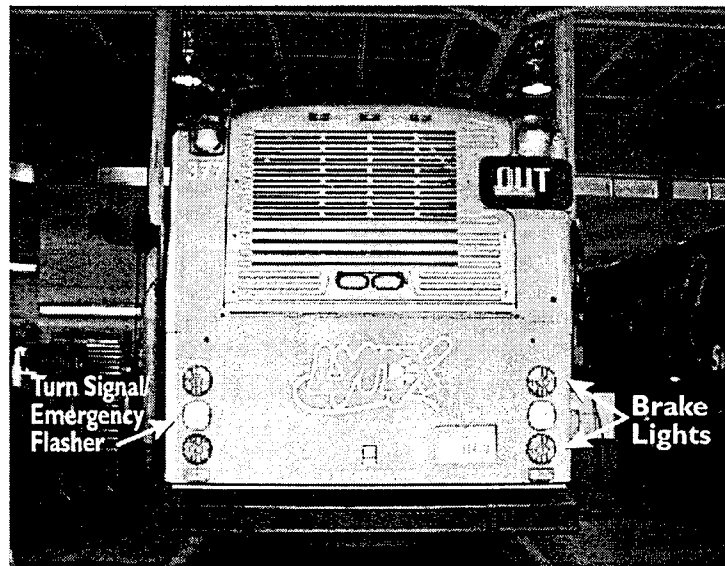
To assist with the evaluation of the effectiveness of this particular safety campaign, LYNX supplied CUTR with a database containing a total of 751 collision occurrence records. Unlike the HART database, LYNX did not include any non-collision occurrence data (e.g., slip-and-falls, etc.), and fewer variables were included for each record than was the case for the HART data. Each record provided the following variables: date and time of the crash, bus number, route number, location, descriptively-assessed (not actual) speed of the vehicles involved, identified preventability status, the type of involvement/impact dynamic (LYNX combines these into a single coding classification), and high density lights implementation status of the bus involved in the crash.

Since the implementation period for the high density lights was from March to December 1998, LYNX provided crash data for the 12 months prior to the implementation period (March 1997 to February 1998) and the 12 months after (January 1999 to December 1999). Given the equal lengths and homogeneity of these two analysis periods, as well as LYNX's inclusion of collision incident data only, it was not necessary to filter the data prior to analysis.

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LYNX maintains some form of electronic occurrence database that is compiled from a selection of information included in the system's accident reports. LYNX staff provided CUTR with a series of printouts from this database that included data specific to the analysis time frame. The information from these printouts was entered into an Excel spreadsheet to create the database that ultimately was utilized for the analyses presented herein for the LYNX case study.

Similar to the HART case study, the LYNX case study includes two separate sections documenting the results of the analyses. The first section reviews basic frequency distribution results for the general characteristics provided by LYNX for all of the crashes included in the two 12-month analysis periods. This evaluation is completed without consideration for the effects of the rear-end high density lights. Then, the second section looks into the systemwide effects of this particular vehicle safety improvement, with specific attention given to changes in pre- and post-implementation crash occurrence for total collisions and for collisions by type of involvement/impact dynamic. A brief cost-benefit analysis is also included in this second section.

General Occurrence Characteristics

SPSS was utilized once again to compile frequency distributions for each of the variables included in the collision occurrence database created with LYNX data. The time period being analyzed in this section is March 1997 to December 1999, exclusive of the 10-month period during which installation of the high density lights occurred (March 1998 to December 1998). In this section, then, this span of time will be referred to as the "study period." The results of the frequency distributions are presented and discussed in this section. This information is useful in setting the context for overall crash occurrence at LYNX during the study period.

Crash Occurrence by Month

Table 20 shows the combined frequency distribution for the months during which the study period crashes occurred. Since the 24-month study period included two months of January (1998 and 1999), the number of crashes that occurred in each were combined to total 54, or 7.2 percent of the 751 total crashes during this time. The last column in the table reflects the per-month crash averages to facilitate comparison of monthly crash occurrence.

The monthly data shown in the table indicate that August has the highest crash occurrence, with an average of 38.5 crashes per month. April and May have the lowest average crash occurrence rate of the months: 26.5 crashes per month each.

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Table 20
Combined Frequency Distribution for Monthly Crash Occurrence

Month	Combined Frequency	Percent Distribution	Average Frequency
January	54	7.2	27.0
February	61	8.1	30.5
March	63	8.4	31.5
April	53	7.1	26.5
May	53	7.1	26.5
June	74	9.8	37.0
July	67	8.9	33.5
August	77	10.3	38.5
September	54	7.2	27.0
October	74	9.8	37.0
November	64	8.5	32.0
December	57	7.6	28.5
Total	**751**	**100.0**	**31.3**

Crash Occurrence by Time of Day

The frequency distribution for the times of the day that the study period crashes occurred are presented in Table 21. LYNX operates fixed-route motorbus service between 4:00 a.m. and 1:30 a.m. during weekdays. This service is provided between 4:00 a.m. and 12:45 a.m. on Saturdays, and from 5:00 a.m. to 12:45 a.m. on Sundays. The time period during which the most crashes occurred is the 5:00 - 5:59 p.m. hour (10.6 percent of crashes with reported occurrence times). Thirty-six percent of all the crashes that had reported occurrence times took place during the four-hour period from 2:00 - 5:59 p.m. As would be expected, the two hours with the lowest crash occurrence are 10:00 - 10:59 p.m. (1.6 percent) and 11:00 - 11:59 p.m. (1.1 percent).

Table 21
Frequency Distribution for Time of Day Crash Occurred

Time of Day	Frequency	Valid % Distribution
6 to 6:59 AM	30	4.3
7 to 7:59 AM	29	4.2
8 to 8:59 AM	41	5.9
9 to 9:59 AM	31	4.4
10 to 10:59 AM	44	6.3
11 to 11:59 AM	45	6.5
12 to 12:59 PM	41	5.9
1 to 1:59 PM	29	4.2
2 to 2:59 PM	61	8.8
3 to 3:59 PM	53	7.6
4 to 4:59 PM	63	9.0
5 to 5:59 PM	74	10.6
6 to 6:59 PM	43	6.2
7 to 7:59 PM	40	5.7
8 to 8:59 PM	28	4.0
9 to 9:59 PM	26	3.7
10 to 10:59 PM	11	1.6
11 to 11:59 PM	8	1.1
Subtotal	697	100.0
Missing	54	---
Total	**751**	---

Crash Occurrence by Route

Table 22 illustrates the frequency distribution for the routes on which the study period's crashes occurred. The five routes with the most collision occurrences are Route 4 (4.5 percent of study period collision occurrences), Route 8 (5.7 percent), Route 17 (4.7 percent), Route 20 (4.3 percent), and Route 41 (4.4 percent). These routes are some of the longest in the system, serving the urban core of the region and operating along major roadways. All but one of the routes primarily operate in the north-south direction. Route 20 is split evenly between operating in the north-south and the east-west directions.

Route 4 operates primarily Orange Blossom Trail and provides service to Osceola County. Route 8 meanders from Downtown Orlando to Sea World, with a large portion of service provided along International Drive. Route 17 operates primarily along Orange Blossom Trail and provides service to Seminole County. Route 20 provides service between Downtown Orlando and the Department of Children and Families along Church Street, Mercy Drive, and Silver Star Road. Finally, Route 41 operates from Apopka to Orlando International Airport along State Road 436.

Table 22 also provides Z-statistics for the analysis of crash occurrence by route. High Z-statistics, 1.40 or higher, can be used to identify routes that are more prone to crash occurrence relative to the other routes in the system. This information can help identify potential problem routes within the system.

Based on the results of this analysis, it may be prudent for LYNX staff to investigate these routes further to identify the reason(s) behind this finding. Factors that may be impacting these specific routes include traffic congestion, roadway geometry and condition, and/or operator characteristics (e.g., experience level, safety record, etc.).

Table 22
Frequency Distribution for Route Where Crash Occurred

Route	Frequency	% Distribution	Z-Statistic	Route	Frequency	% Distribution	Z-Statistic
1	5	0.7	-0.7069	31	15	2.0	0.3189441
2	5	0.7	-0.7069	32	7	0.9	-0.501731
3	7	0.9	-0.501731	33	2	0.3	-1.014653
4	34	4.5	2.2680475	34	1	0.1	-1.117237
6	4	0.5	-0.809484	35	5	0.7	-0.7069
7	8	1.1	-0.399147	36	12	1.6	0.0111909
8	43	5.7	3.191307	37	13	1.7	0.1137753
9	13	1.7	0.1137753	38	10	1.3	-0.193978
10	3	0.4	-0.912069	39	18	2.4	0.6266973
11	23	3.1	1.1396192	40	15	2.0	0.3189441
13	20	2.7	0.831866	41	33	4.4	2.1654631
14	10	1.3	-0.193978	42	25	3.3	1.344788
15	15	2.0	0.3189441	43	6	0.8	-0.604315
16	12	1.6	0.0111909	44	2	0.3	-1.014653
17	35	4.7	2.3706319	45	2	0.3	-1.014653
18	17	2.3	0.5241129	46	3	0.4	-0.912069
19	17	2.3	0.5241129	47	3	0.4	-0.912069
20	32	4.3	2.0628787	48	11	1.5	-0.091393
21	18	2.4	0.6266973	49	6	0.8	-0.604315
22	7	0.9	-0.501731	50	6	0.8	-0.604315
23	11	1.5	-0.091393	51	20	2.7	0.831866
24	5	0.7	-0.7069	54	2	0.3	-1.014653
25	16	2.1	0.4215285	56	9	1.2	-0.296562
26	6	0.8	-0.604315	99	1	0.1	-1.117237
27	11	1.5	-0.091393	200	3	0.4	-0.912069
28	12	1.6	0.0111909	333	3	0.4	-0.912069
29	12	1.6	0.0111909	801	1	0.1	-1.117237
30	19	2.5	0.7292816	Missing	97	12.9	---
				Total	751	100.0	---

Each of the routes with a Z-statistic over 1.40 was examined for its types of collisions (i.e., Routes 4, 8, 17, 20, and 41). Rear end collisions encompassed the greatest proportion of crashes on Routes 4, 8, 17, and 41. As noted previously in the HART case study, road geometry often can play a role in the occurrence of rear end collisions. For example, it is possible that a vehicle can rear end a slowing or stopped bus if the vehicle's driver is operating in an inattentive, aggressive, and/or negligent manner and the roadway does not offer a shoulder or other opportunity for recovery. It is logical, then, that buses operating along roadways without shoulders or multiple lanes (or with heavy volumes of traffic) are more susceptible to rear end impacts. These four routes with a higher

incidence of rear end collisions simply may be operating in route environments that cultivate this type of impact.

The examination of Route 20 shows that, although this route also has a high incidence of rear end collisions (approximately 22 percent of all crashes on this route), the highest crash type occurrence actually involves a bus hitting another vehicle (28 percent of all crashes on this route).

Crash Occurrence by Identified Preventability Status

The frequency distribution for the identified preventability status (i.e., whether a crash is preventable or non-preventable) of the LYNX study period crashes is presented in Table 23. As the data in the table indicate, 71.3 percent of the crashes that occurred during the two-year study period were classified as non-preventable by the system.

Table 23
Frequency Distribution for Identified Preventability Status of Crashes

Preventability Status	Frequency	Valid % Distribution
Preventable	214	28.7
Non-Preventable	532	71.3
Missing	5	---
Total	751	---

Crash Occurrence by Type of Involvement/Impact Dynamic

This particular analysis examines the distribution of each type of collision that occurred during the study period. LYNX utilizes occurrence coding that combines the involvement type with the actual impact dynamic. The coding used by LYNX includes eight different forms of collisions: a bus hitting another transit vehicle, a bus hitting a car, a broadside collision, a collision with a fixed object, a head-on collision, a hit and run, a rear end collision, and a sideswipe.

In Table 24, a frequency distribution is presented for the various types of involvement/impact dynamic. In addition, the percent of preventable crashes within each involvement/impact dynamic category is shown, as well. By far, the most frequent type of collision in the data set is the rear end collision. Rear end collisions are responsible for almost one-third of all the study period's crashes. It is anticipated that this is the reason that LYNX selected a safety campaign that specifically is

targeted to reduce the number of rear end collisions. It also should be noted that 37 percent of the data set is described by an event where the bus hit an object (combination of the categories where the bus hit another bus, a car, or a fixed object). Considering the identified preventability status of these crashes, this particular type of collision is preventable more than 58 percent of the time.

Table 24
Frequency Distribution for Type of Involvement/Impact Dynamic

Type of Involvement/Impact Dynamic	Frequency	Percent Distribution	Percent of Preventable Crashes Within Each Category
Bus Hit a Transit Vehicle	54	7.2	75.9
Bus Hit a Car	104	13.8	76.0
Broadside	28	3.7	3.6
Fixed Object	122	16.2	35.2
Head On	85	11.3	8.2
Hit and Run	53	7.1	0.0
Rear End	242	32.2	10.7
Side Swipe	62	8.3	27.4
Missing	1	0.1	---
Total	**751**	**100.0**	**28.5**

Crash Occurrence by Speed of Bus

As noted in the introduction to the case study, LYNX took into account the descriptively-assessed (not actual) speed of the bus at the time of the crash. Table 25 provides the frequency distribution for the speed of the bus at the time of the study period crashes. As shown, the bus was stopped 43.7 percent of the time when an crash occurred. In addition, the bus was operating at a slow speed at the time of involvement for 45.3 percent of the study period crashes. It is logical that these two assessed vehicle speeds correlate to the high incidence of rear end collisions discussed previously.

Table 25
Frequency Distribution for Speed of Bus at Time of Crash

Vehicle Speed	Bus	
	Frequency	Valid % Distribution
Stopped	273	43.7
Slow	283	45.3
Moderate	66	10.6
Fast	3	0.5
Unknown	126	---
Total	751	---

Summary of General Occurrence Characteristics

The review of the frequency distributions completed for the occurrence characteristics in LYNX's occurrence database suggest that a "typical" crash during the study period occurred:

- during the month of August;
- between the hours of 5:00-5:59 p.m.;
- on Route 8;
- as a rear end collision with the bus being hit from behind;
- while the bus was either stopped or operating at a slow speed; and
- as a non-preventable crash.

Analysis of the Impact of LYNX High Density Lights

As noted previously in the introduction to this case study, LYNX provided crash data for the 12 months prior (March 1997 to February 1998) to the high density light implementation period and the 12 months after (January 1999 to December 1999) the implementation period. Again, given the equal lengths and homogeneity of these two analysis periods, as well as the inclusion of only collision data, it was not necessary to create pre- and post-databases or filter the data prior to analyzing the impact of the high density light safety campaign. Instead, to facilitate the analysis, the data set for each period was separated into two groups of vehicles: vehicles that do not receive high density lights during the time of the analysis (the control group) and vehicles that are scheduled for and do receive the new lights during the time period of the study (the experimental group). The basic purpose of these groups is to reveal more fully the comparative effects of the campaign on crash occurrence, i.e., what would happen occurrence-wise if the vehicles did not get the high

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density lights (control) versus what would happen if they did (experimental). In all, a total of 750 crash records were included in this analysis. Only one of the original 751 records could not be utilized; it did not have bus number information available to be able to determine whether the bus received high density lights.

Impact of High Density Lights on Overall Crash Occurrence

Table 26 describes the effect that the implementation of the high density lights had on crash occurrence between the two study periods (i.e., the 12 months prior to the safety campaign versus the 12 months after the campaign). The table provides information on the number of crashes and the number of motorbus vehicles in each of the study period data sets for the control and experimental groups.

Table 26
Change in Crash Occurrence Per Vehicle

Variables	Pre-Implementation (3/97 - 2/98)		Post-Implementation (1/99 - 12/99)		Percent Change	
	Control	Experiment	Control	Experiment	Control	Experiment
Crashes in Data Set	115	228	179	228	---	---
Vehicles in Data Set	71	113	86	107	---	---
Crashes per Vehicle	1.6197	2.0177	2.0814	2.1308	28.5	5.6

It is important to understand that the data being analyzed in this table represent only the information that was provided in LYNX's original database. That is, the 750 total crashes correspond to the 750 usable (i.e., with a valid bus number available) collision occurrence records included in the database. Similarly, the vehicles represent all of the motorbus vehicles in the LYNX database, i.e., those buses that were involved in at least one collision occurrence either during the 12 months prior to the safety campaign implementation or during the 12 months after. It is the case that any one vehicle may have been involved in more than one crash, either in the pre- or post-implementation period, or in both. It is also possible that a vehicle included in one study period may not be represented in the other because it was not involved in an crash during that time. Regardless, this sample of motorbus vehicles is assumed to mirror the characteristics of the population of LYNX's entire bus fleet. This means that all vehicles included in this analysis are assumed to accumulate typical annual vehicle miles/hours and to be rotated regularly among all LYNX routes per Title VI guidelines, thereby ensuring uniform utilization and exposure to similar roadway and traffic characteristics.

Given these assumptions, it is evident in the table that crash occurrence increased (from 115 to 179 crashes) for the control group between the study periods, while it remained perfectly stable (at 228 crashes) for the experimental group. This is a positive result until one considers that the number vehicles contributing to the crash occurrence increased for the control group, but declined for the experimental group, during the same time. This is why the ratio of crashes to vehicles is a better variable for comparative analysis (due to its accounting for exposure through the proxy of vehicles), and will be utilized throughout the rest of this section.

Looking at the crash per vehicle ratios, it is the case that the control group's crash rate increased 28.5 percent between the pre- and post-implementation periods, from 1.62 to 2.08 crashes per vehicle. This means that, had LYNX not implemented high density lights on any of its vehicles, it would be expected that overall crash occurrence for the system would have gone up by more than 28 percent. Comparatively, the experimental group's crash rate increased only 5.6 percent between the two periods, from 2.02 to 2.13 crashes per vehicle. Therefore, the experimental group showed an improvement (approximately 23 percent) in the occurrence of crashes over the control group. This means that, had LYNX implemented high density lights on all of its vehicle fleet, one would expect overall crash occurrence to increase less than six percent between the two time periods.

Impact of High Density Lights on Crash Occurrence by Type of Involvement/Impact Dynamic

Table 27 examines the effect that the capital improvement had on each crash's type of involvement/impact dynamic. The control group showed decreases in two of the eight different types of involvement/impact dynamics: broadside and sideswipe. The experimental group indicated a decline in four of the eight different types: bus hit a transit vehicle, broadside collision, rear end collision, and sideswipe. Sideswipes experienced a 100 percent decrease and broadside collisions experienced a 95 percent decrease for the experimental group. Also, collisions between transit vehicles decreased by 11.8 percent. Most importantly, however, rear end collisions decreased by almost 13 percent. The category to experience the most significant increase in either group was head on collisions. It is surmised that this event may have occurred due to a change in the definition of "head on collisions," because, by their nature, this type of involvement/impact dynamic is not a very common occurrence.

It is also important to point out that, based on frequency distributions for the types of involvement/impact dynamics by study period, the proportion of rear end crashes as a percent of all crash types decreased from 34.1 percent in the pre-implementation period to 30.7 percent in the post-implementation period.

Table 27
Change in Crash Occurrence by Type of Involvement/Impact Dynamic

Type of Involvement/Impact Dynamic	Pre-Implementation (3/97 - 2/98)		Post-Implementation (1/99 - 12/99)		Percent Change	
	Control	Experiment	Control	Experiment	Control	Experiment
Bus Hit a Transit Vehicle	7	17	15	15	114.3	-11.8
Bus Hit a Car	23	24	29	28	26.1	16.7
Broadside	4	23	0	1	-100.0	-95.6
Fixed Object	17	35	31	39	82.4	11.4
Head On	1	1	30	53	2900.0	5200.0
Hit and Run	7	10	13	23	85.7	130.0
Rear End	38	79	56	69	47.4	-12.7
Side Swipe	18	39	5	0	-72.2	-100.0
Total	**115**	**228**	**179**	**228**	**55.6**	**0.0**

The information provided in Table 27 has been presented to illustrate the general effect of the safety campaign on the different types of involvement/impact dynamics. However, it is expected that the true impact of the rear-end, high density lights only will be on rear end collision occurrence. Table 28, then, accounts for this expectation by more closely analyzing the change in rear end crash occurrence between the two study periods. This table also addresses the issue of exposure by presenting calculations for the ratios of crashes to vehicles for the groups in each study period.

Table 28
Change in Crash Occurrence Per Vehicle by Rear End Impacts

Variables	Pre-Implementation (3/97 - 2/98)		Post-Implementation (1/99 - 12/99)		Percent Change	
	Control	Experiment	Control	Experiment	Control	Experiment
Rear End Crashes in Data Set	38	79	56	69	---	---
Vehicles in Data Set	71	113	86	107	---	---
Crashes per Vehicle	0.5352	0.6991	0.6512	0.6448	21.7	-7.8

In Table 28, when exposure is taken into account, it is evident that the control group's rear end crash rate per vehicle increased 21.7 percent between the pre- and post-implementation periods, from 0.5352 to 0.6512 rear end crashes per vehicle. As indicated previously, this suggests that, had

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LYNX not implemented high density lights on any of its vehicles, one would expect rear end crash occurrence for the system to increase almost 22 percent between the two periods. It is anticipated that this level of increase may be attributable to the growth in traffic and congestion in the Orlando metropolitan area and the rest of LYNX's three-county service area during this time.[4]

Conversely, the rear end crash rate for the experimental group actually declined 7.8 percent between the two study periods, from 0.6991 to 0.6448 rear end crashes per vehicle. Compared to the control group's result, this is an improvement in the occurrence of rear end crashes between the periods of nearly 30 percent. This also implies that a full implementation of high density lights on LYNX's vehicle fleet would have been expected to result in nearly an eight percent decline in rear end crash occurrence between the two periods. This key finding suggests that the implementation of the high density light safety campaign qualifies as a success, especially given the fact that rear end crash occurrence increased about 22 percent for vehicles without the new lights.

Economic Analysis of the Impact of High Density Lights

According to LYNX staff, the total capital cost for acquiring the rear-end high density lights for the system's Gillig and Orion V fleets was $60,426. LYNX's vehicle inventory in its FY 1999 National Transit Database report indicates that the system had 195 Gilligs and Orion Vs in its fleet that year. This suggests an average capital cost per bus of $309.88. Therefore, it would cost LYNX approximately $69,100 to outfit its entire FY 1999 fleet of 223 active vehicles with the high density lights. It is important to recognize, however, that this cost does not include labor and/or any other installation costs. Typically, the total economic cost of such a campaign would be the cost of capital acquisition, the cost of labor/installation, any revenue lost during installation, and the life cycle costing of the components. Examining only rear end collisions, based on the decline in rear end crash occurrence, it is expected that the economic benefit of this campaign would be approximately a 7.8 percent reduction in the cost of repair, in revenue lost, and in litigation costs.

Unfortunately, LYNX was unable to provide average cost data for its collision occurrences, rear end or otherwise. However, as an example, if it is assumed that the system has an annual total economic cost of $500,000 for its rear end collisions, then this capital improvement, displaying similar effects, can bring a reduction of $39,000 (or -7.8 percent of $500,000) in the annual

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[4] According to FDOT's Public Road Mileage and Miles Traveled reports, daily VMT for all public roads in the urbanized portions of Orange, Osceola, and Seminole County increased 7.7 percent between 1997 and 1999 (from 32.9 million daily VMT in 1997 to 35.7 million daily VMT in 1999).

economic cost. With such a reduction, the accounting cost of the capital improvement (i.e., the high density lights) would be recovered within two years.

Summary of the Impact of High Density Lights

Based on the analyses completed in this section, key findings on the impacts of LYNX's rear-end high density lights are as follows:

- average per vehicle crash occurrence increased 28.5 percent between the pre- and post-implementation periods for those LYNX buses not outfitted with the high density lights (i.e., the control group);
- average per vehicle crash occurrence increased only 5.6 percent between the study periods for LYNX buses outfitted with the high density lights (i.e., the experimental group);
- the proportion of rear end crashes, as a percent of all occurrence types, decreased from 34.1 percent in the pre-implementation period to 30.7 percent in the post-implementation period;
- in absolute terms, rear end crash occurrence decreased 12.7 percent between the two study periods for LYNX buses outfitted with high density lights, but went up 47.4 percent for buses without the new lights;
- rear end crash rates per vehicle increased 21.7 percent between the study periods for LYNX buses without the high density lights, but decreased 7.8 percent between the periods for buses with the new lights, resulting in a 29.5 percent decline from the anticipated outcome regarding rear end crash occurrence; and
- it is anticipated that, given similar annual improvements in the occurrence of rear end crashes, and depending on the actual total annual economic costs of this specific type of crash, LYNX may be able to recoup the initial capital outlay for outfitting its entire fleet with the high density lights in only a few years.

In summary, the evaluation of LYNX's capital safety improvement (i.e., the rear-end high density lights) indicates that this particular campaign was successful in helping to mitigate the occurrence of rear end collision impacts during the study period analyzed. As noted in the bulleted key findings, between the pre- and post-implementation periods, the rear end crash rate per vehicle decreased 7.8 percent for vehicles with the high density lights, while the comparative rate for vehicles without the new lights increased 21.7 percent.

Similar to the case for HART's refresher training course, it is equally important to learn from the process of the evaluation, itself, as it is from the results. For example, one important aspect of this type of evaluation is the comparison of the fully-allocated cost of implementing the high density lights on LYNX's vehicle fleet versus the cost savings that may be realized from any resulting reduction in rear end crash occurrence. While an attempt was made to estimate this comparison based on the limited information available, LYNX would be better served by conducting a more specific cost-benefit evaluation of this capital safety campaign.

Therefore, for future evaluation of this or any other safety programs, LYNX should ensure that all costs associated with its crashes and capital improvements (both physical and human) are continuously collected and maintained. In the case of the high density light campaign, for example, full costs would include the capital purchase costs of the equipment, labor/installation costs, and any other expenditures related to the implementation of the lights (e.g., overtime for maintenance personnel to install lights). As was recommended for HART, LYNX also would be well served by developing a specific evaluation process for any future safety-related campaigns that are planned for implementation, whether capital or training, prior to the initiation of the campaign.

SUMMARY AND CONCLUSIONS

To summarize, in this project, transit bus occurrence data from selected Florida transit systems were reviewed to analyze changes in crash occurrence over time in relation to the effectiveness of specific safety campaigns in reducing bus crashes. Two systems were selected to complete this investigation: Hillsborough Area Regional Transit Authority (HART) in Tampa and LYNX Transit in Orlando. HART was included to analyze the effectiveness of a safety campaign involving an operator refresher training course. LYNX was included to analyze the effectiveness of a safety campaign involving a vehicle-related capital improvement (i.e., rear-end high density lights). This report has documented the case study analyses of these safety campaigns and their effectiveness in positively impacting crash occurrence at the two systems.

The overall findings of the HART case study, unfortunately, cannot definitively prove the success of the refresher training course. While it does appear that some measurable benefit was gained as a result of the program, contradictory results were also identified. For instance, the evaluation does indicate that crash occurrence declined after the three-month period during which the course was conducted. In absolute terms, total collision occurrences declined 2.3 percent between the pre- and post-training study periods. Additionally, when taking into account exposure, the number of revenue hours between (all) crashes increased 4.4 percent between the two periods, as well. However,

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despite the decrease in total collision occurrences, preventable crashes (which is the type of crash occurrence that one would expect to be impacted in a positive manner the most by refresher operator training) increased more than 50 percent between the two study periods. Such a result may be an indication that the course did not emphasize or specifically cover training that would lead to the reduction of this type of crash. It is also the case that HART had a significant influx of new drivers beginning about the time the course was originally offered, which had a strong influence on the pre- and post-training analyses, as well. During the pre-training analysis period, drivers with less than three years of experience accounted for 22 percent of all collision occurrences and 27 percent of all preventable collision occurrences. However, after the refresher training course, these proportions increased to 46 percent and 61 percent, respectively. With this impact of the increased number of new, inexperienced drivers at HART on crash occurrence, it is difficult to fairly assess the actual level of effectiveness of the refresher training program conclusively.

In the case of LYNX, it is apparent from this case study that the system's motorbuses have been experiencing a particular problem with rear end collision impacts and that the rear-end high density light campaign has had a beneficial impact on this issue. In the database provided by LYNX, rear end collisions accounted for almost a third of all the crashes that occurred during the two-year period for which data were included. To help mitigate this type of involvement, LYNX chose to implement the rear-end high density lights on many of its vehicles. In analyzing the impact of this capital safety improvement on crash occurrence during pre- and post-implementation periods, it was determined that vehicles outfitted with the high density lights experienced a 7.8 percent decline in per vehicle rear end crash rates. Even more significant is the fact that vehicles without the upgraded lights experienced a 21.7 percent increase in per vehicle rear end crash rates during the same time period. These comparative percentage changes suggest that, overall, there was a 29.5 percent decline from the level of rear end crash occurrence that would have been expected had the high density lights not been implemented at all. This is clear indication that the high density lights have been successful in helping LYNX lessen the rear end crash occurrence problems that the system had been having.

In conclusion, then, based on the results of the analyses contained herein, it is apparent that the high density light campaign implemented by LYNX was quite successful in helping to deter the occurrence of rear end collisions. Additionally, while the refresher training course conducted by HART had beneficial impacts on the system's overall crash occurrence, it could not be conclusively analyzed for absolute effectiveness. Nevertheless, aside from what was learned from the results of these case studies, the analysis process utilized in each was beneficially instructional, as well.

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One of the most enlightening aspects of the case studies involved the process to acquire the data necessary to complete each evaluation. As noted previously in this document, the most difficult part of either analysis involved this data collection phase – a phase over which CUTR had no control, unfortunately. In each case, the systems utilize relatively extensive accident reporting forms to collect information at the time of each occurrence and the original forms are kept in usable order by Risk Management personnel. Both systems have also managed to input varying portions of their respective occurrence data into electronic databases (for example, HART includes specific occurrence data in its FleetNet database). To extract the variables that were needed for these analyses, however, proved to be a difficult and time-consuming effort.

One major issue that needed to be dealt with involved the systems' concern for the anonymity of their drivers in each occurrence record. In fact, several discussions were needed initially with the system's respective Risk Management personnel just to convince them to allow the use of the data. A primary concern was allowing CUTR staff access to the accident reports so that the necessary information could be collected and entered into a usable database. Finally, the systems agreed to compile the occurrence data themselves in order to protect any "classified" information.

This process resulted in a second key issue. A major shortcoming of this procedure was that the systems only provided occurrence information that had been incorporated into their electronic databases. This meant that, in each case, a number of desirable variables could not be provided for analysis. It also made it necessary for CUTR to request supplementary information that was crucial to the analyses, such as driver hire dates to calculate operator tenure at the time of each crash and operator platform hours to be able to account for driver exposure. In addition, other information important to the completion of the analyses, such as crash and safety improvement costs, were difficult to obtain and, in some cases, not available or known.

These issues resulted in a data collection process that took an inordinate amount of time and effort to complete and hindered particular aspects of the analyses. Because of this fact, it may be beneficial to reintroduce the major recommendation of the "Enhancing Safety In Florida Transit Systems" project that CUTR completed for FDOT in June 1998. In this project, a process to help Florida transit agencies track and analyze their bus crashes was developed to help the systems determine common causal factors and/or measure the success of their occurrence prevention efforts. The process involved five basic steps that should be followed by transit agencies when analyzing crash occurrence data and developing corrective action plans for addressing identified problem areas. The five steps are as follows:

1. Collection of the data
2. Preparation of the data for analysis
3. Analysis of the data
4. Interpretation of the results
5. Action plan to deal with identified issues/problems

The data collection step is the one which created the most difficulty for this current evaluation effort. This first step involves the collection and compilation of occurrence data, and the earlier project recommended the collection of a core set of characteristics that are fundamental in analyzing a system's crash occurrence data for purposes of safety campaign implementation. At the time of this previous project, it was recommended that the FDOT request that all of the Florida public transit systems collect the core set of crash occurrence characteristics that is detailed below. The reasoning for this recommendation was that the availability of this information on a system-by-system basis would allow for not only similar analyses and comparisons between systems, but also for a comprehensive analysis of crash occurrence throughout the State.

In the following list, those crash occurrence characteristics shown in bold are the <u>key</u> data elements that would be required for most safety campaign assessments. These key characteristics should be the minimum required elements if transit systems choose to create secondary electronic databases from their occurrence records. While the inclusion of any of the other crash information is not necessary, it is up to the individual systems to decide on what other elements they wish to include. These supplemental data will only help to make any further analyses more thorough.

- **Date, day of week, and time of day of occurrence**
- **Specific location of occurrence (intersection, cross street, plaza, mall, other key location)**
- Location of stop (near-side, far-side, mid-block)
- Roadway surface type (concrete, asphalt, brick, gravel)
- **Roadway geometry (number of lanes, configuration, posted speed, traffic control)**
- **Roadway conditions (wet, dry, under repair, holes/ruts, muddy, no defects)**
- Weather conditions (clear, cloudy, raining, foggy, other)
- **Light conditions (daylight, glare, dawn, dusk, dark w/streetlights on, dark w/streetlights off, dark w/no streetlights)**
- Traffic conditions (light, moderate, or heavy)
- **Route number**
- **Vehicle type, manufacturer, and year of manufacture**
- Observed vehicle defects prior to or at time of crash (steps, floors, seats, brakes, lights) and date of last scheduled preventative maintenance

- **Operator hire and termination date (to be used to calculate years of experience at time of occurrence)**
- Operator status (regular operator, regular relief, vacation relief, mini-run, extra board, mechanic, supervisor, service attendant)
- **Date of operator's last refresher training course**
- **Occurrence impact dynamic (head on, sideswipe, right angle, rear end, non-collision, bus hit other, bus was hit, other)**
- **Type of involvement (fixed object, moving vehicle, parked vehicle, pedestrian, cyclist, projectile)**
- Transit vehicle movement prior to/at time of occurrence (going straight, turning left, turning right, pulling into curb or loading zone, pulling away from curb or loading zone, passing, being passed, changing lanes, merging, sudden stop, slowing/braking, stopped in traffic lane, stopped in loading zone, parked, backing, starting, other)
- Movement(s) of other vehicle(s) involved prior to/at time of occurrence (going straight, turning left, turning right, pulling into curb or loading zone, pulling away from curb or loading zone, passing, being passed, changing lanes, sudden stop, slowing/braking, stopped in traffic lane, stopped in loading zone, parked, backing, starting, other)
- Pedestrian/cyclist movement prior to/at time of occurrence (walking/ running/riding with traffic, walking/running/riding against traffic, stationary, working in roadway, playing in roadway, unknown, other)
- Pedestrian/cyclist action related to location of occurrence
  - At intersection (in crosswalk, not in crosswalk, no crosswalk, with sign/ signal, against sign/signal, no sign/signal)
  - Not at intersection (crossing diagonally, crossing in front of vehicle, crossing from behind vehicle, getting in/out of other vehicle, crossing from between parked cars, other)
- Passenger movement prior to/at time of occurrence (waiting, boarding, alighting, standing in vehicle, moving in vehicle, sitting in vehicle, on lift, other)
- Observed condition of other driver/pedestrian/cyclist/passenger (influenced by alcohol/intoxicated, sober, sleepy/fatigued, infirmed, wearing glasses, carrying objects, with an observable disability, no observable disability, other)
- Contributory factors (vehicle double-parked, vehicle in crosswalk, pedestrian jaywalking, vehicle pulled out in front, vehicle parked at angle, vehicle parked in zone, other)
- Evasive action(s) taken by driver (hard braking, swerve, other)
- **Identified preventability status of occurrence**

FUTURE SAFETY-RELATED RESEARCH

As part of this project, telephone interviews were conducted with Safety Coordinators at the larger transit systems in Florida. Based on information that was gathered during this process, a number

of safety issues and/or campaigns were identified that suggest further research. This research may involve establishing the characteristics and validity of the issues, as well as possible solutions, and evaluating the cost-benefit of the campaigns. Some of the issues/campaigns identified include:

- Operator fatigue related to the combination of hours, shifts, and days worked versus non-work hours. For example, one analysis may involve a property that has required mandatory overtime to fulfill service due to the unavailability of new drivers. As a result of this circumstance, a driver may work a longer than normal day, a shorter than normal split between work shifts, or an inordinate amount of hours during one work week.

- Following up on the LYNX rear-end high density light campaign, other campaigns geared to the reduction of rear end crashes could be analyzed. These campaigns could include reflective striping, implementation of a lighted message sign (typically saying "STOP"), or other light configurations. The campaigns could be evaluated individually, as well as in comparison to each other with regard to effectiveness and cost-benefit.

- Other types of safety training/refresher training courses could be evaluated for effectiveness and/or cost-benefit. As evidenced by the HART results, these are the most difficult campaigns to assess because of the issue of having to deal with "human" capital improvements. Nevertheless, additional research in this area may prove to be beneficial in establishing the positive impacts of this type of campaign.

- One interesting area of research would be an crash occurrence comparison of transit buses versus school buses. It would be interesting to compare and contrast the crash characteristics and rates of these two types of vehicles, and the safety campaigns instituted by each of their operating agencies.

It should be recognized, however, that, regardless of the particular campaigns and issues that are considered for research, the actual process of reviewing potential safety improvements, their effectiveness, and any cost-benefits that can be achieved still is the most important and beneficial component of any research effort. Because of this, beyond CUTR and FDOT's independent research of safety campaigns at the Florida transit properties, it also may be beneficial to collect analysis and research results of the effectiveness and/or cost-benefits of safety campaigns at transit systems elsewhere in the U.S. This information then can be compiled into a concise, user-friendly resource that can be disseminated throughout the transit industry. Such a resource would also be a positive step in establishing a comprehensive catalogue of safety improvements/campaigns and

their associated costs and "rule of thumb" occurrence prevention effectiveness levels – as noted in the introduction to this study, a desired outcome of the research that CUTR and FDOT currently is completing. Such a catalogue would greatly assist transit systems in Florida, the U.S., and elsewhere in their selection of appropriate safety campaign(s) for meeting their financial and safety goals.